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STABILIZATION OF SOIL USING CHEMICAL COMPOUNDS AND THEIR COMPARATIVE ANALYSIS

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ABSTRACT

This study is mainly concerned with the different types of laboratory experiments to evaluate the improvement of engineering properties of soil stabilized by NaCl and $CaCl_2$ and comparison between stabilized and untreated soil. The strength developed on stabilized soil depends on several factors like natural water content, optimum moisture content, compaction, proper mixing etc. The soil sample was collected from the KUET campus at a depth of 5 feet from the existing surface. In the laboratory, the natural moisture content, liquid limit, plastic limit, specific gravity, grain size distribution, standard proctor test, unconfined compressive strength test was performed to find out the relevant value of collected soil. By using plasticity chart the collected soil is classified as inorganic silt with low plasticity and the group symbol (according to USCS) is denoted as ML. The sample is prepared with varying the mixture proportion of soil and chemical additives (NaCl, $CaCl_2$) in the range of 2, 4, 6, 8 and 10%. The unconfined compressive test has been carried out to evaluate the effectiveness of NaCl and $CaCl_2$ in improving the strength behavior of soil. The standard Procter test is conducted to examine the change in optimum moisture content and maximum dry density of soil due to addition of chemical additives. The addition of NaCl and $CaCl_2$ used in this study decreased the liquid limit, plastic limit and plasticity index up to 6%, beyond this percentage the liquid limit, plastic limit and plasticity index increased to some extent. A significant increase in maximum dry density with increase the percentages of the NaCl and $CaCl_2$ up to 6%, beyond this percentage the maximum dry density rapidly decreased and vice-versa for optimum moisture content. The unconfined compression strength increases up to 6% addition of chemical compounds, beyond this percentage the UCS rapidly decreased. It has been observed about 6% replacement of soil by NaCl or $CaCl_2$ is most effective in improving the strength behavior of soil. It is also observed that optimum moisture content of stabilized soil generally increases and maximum dry density decreases due to increase of the replacement of soil by NaCl or $CaCl_2$ at 6%.

Keyword: *Chemical Stabilization, Atterberg Limit, Standard Proctor Test, Unconfined Compression Tests*

1. INTRODUCTION

Bangladesh is a land of delta formation with alluvial deposition. So, soft ground are found almost everywhere in the country. Soft ground creates problems for the construction of structures such as buildings, roads and highways, railways, airfields, embankments, dams and various civil engineering works due to its very low strength. Moreover make the construction cost very expensive. Khulna region is the southwest part of Bangladesh. The valuable structures are sometimes collapsed due to excessive total or immediate settlement of the structures while constructed on the soft ground without adopting proper foundation. Many of the researchers have worked out on this topics to develop an effective solution for the construction of structures on soft ground. For the practice of improving the condition of soil, chemical compounds are used for increasing the strength of the soil (Shon, 2010).

A difficult problem in civil engineering works exists when the sub-grade is found to be clay soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase (Chen, 1981). Many research have been done on the subject of soil stabilization using various additives, the most common methods of soil stabilization of clay soils in pavement work are cement and lime stabilization. The high strengths obtained from cement and lime stabilization may not always be required, however, and there is justification for seeking cheaper additives which may be used to alter the soil properties (Nagaraj, 2014).

Soil stabilization refers to the procedure in which a special soil, a cementing material, or other chemical material is added to a natural soil to improve one or more of its properties. One may achieve stabilization by mechanically mixing the natural soil and stabilizing material together so as to achieve a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposit and obtaining interaction by letting it permeate through soil voids (Perloff W. H., 1976). Where the soil and stabilizing agent are blended and worked together, the placement process usually includes compaction.
Soil stabilizing additives are used to improve the properties of less–desirable rood soils. When used these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and waterproofing agents (Janathan Q. Addo, 2004).

The stabilization of soils with chemical compounds is a technique commonly used to improve soil properties (Afrin, 2017). This study is mainly concerned with different types of laboratory experiments to evaluate the improvement of engineering properties of soils using chemical compounds and compare between treated and untreated soil. In this study, NaCl and $CaCl_2$ will be used for improving engineering properties of soils. Chemical in the range of 2, 4, 6, 8, 10 and 12% will be mixed with soil samples and compared the engineering properties of stabilized soils.
This study describes an investigation into the effect of addition chemical compounds (NaCl, $CaCl_2$) on the engineering properties of clay soil which was collected from the KUET campus. Chemical compounds like NaCl and $CaCl_2$ were selected because these chemicals are available in Khulna city and it is also a common component of salts.

2. METHODOLOGY

2.1 Collection of soil sample and laboratory investigations

The soil at a depth of 5 feet from the existing ground surface from KUET campus was collected. The physical and index properties of soil sample were measured through ASTM standards test methods are provided in Table 1.

Table 1: Physical and index properties of soil used in this study

Properties	Values
Liquid limit, LL (%)	34
Plastic limit, PL (%)	25
Plasticity index, PI (%)	8
Specific gravity (Gs)	2.72
Sand: Silt: Clay (%)	17.9 : 52.9 : 29.2
Maximum dry density, MDD (kN/m^3)	17.47
Optimum moisture content, PMC (%)	15.61
Unconfined compression strength, UCS (kN/m^2)	65.79
USCS	ML

The collected soil samples were dried into air and then crushed to make into dust manually. The soil was stored in covered place. The soil was allowed to dry in the oven for 24 hours before performing any test on it. The quantity of soil required for each test was taken from oven every time and allowed to cool at room temperature. Soil was sieved through #16 sieves.

2.2 Preparation of stabilized soils

In this study, the chemicals like NaCl and $CaCl_2$ were used for improving engineering properties of untreated soils. Chemicals in the range of 2, 4, 6, 8 and 10% were mixed with untreated soil sample.

3. ILLUSTRATIONS

The effect of chemicals on Atterberg limit, compaction properties and unconfined compressive strength (UCS) of stabilized soils have been analyzed. Comparison was also made for untreated and stabilized soil with chemicals used in this study and hence discussed in the following articles.

3.1 Effect of chemicals on Atterberg Limit

In this study, stabilized soils were prepared with NaCl and $CaCl_2$ in the range of 2, 4, 6, 8 and 10 percentage of soil and the Atterberg limits in terms of LL, PL, PI of stabilized soils were measured. The variation of Atterberg limits with in relation to the changes of mixing proportions of chemicals is shown in figure 1.

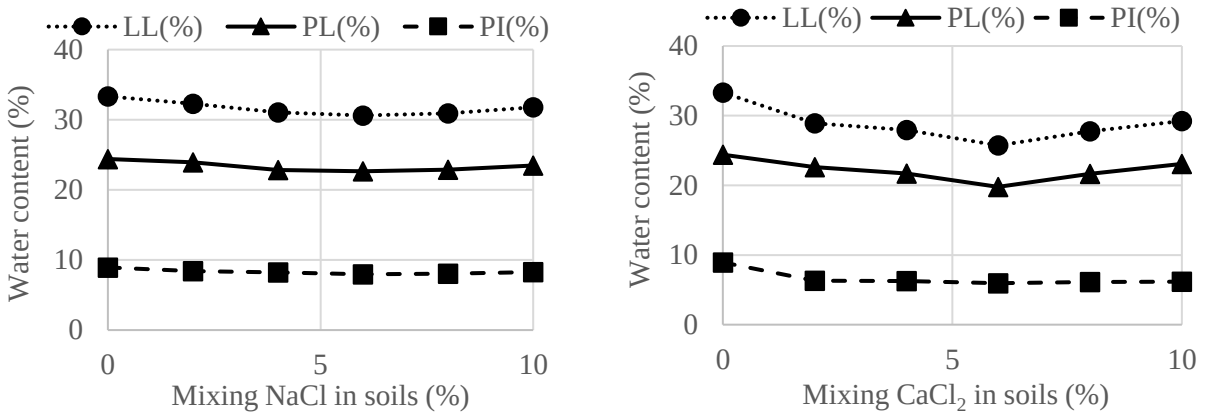

Figure 1: Effect of (a) NaCl and (b) $Cacl_2$ on Atterberg limits of stabilized soils

It was observed that there is a significant decrease in LL, PL and PI with increase the percentages of the $CaCl_2$ up to 6%, beyond this percentage the LL, PL and PI increased to some content. This is due to the decrease in the thickness of the diffused double layer as the salt content increased. The liquid limit, plastic limit and plasticity index decreased as the salts content increased. Similar results were reported by Venkatabor & Reach (Venkatabor Rad, 1977) this behavior is due to the decrease in the thickness of the diffused double layer as the salt content increased.

3.1.1 Comparison of plasticity index of stabilized soils with chemicals

The comparison of PI of stabilized soils with both chemicals is shown in Figure 2. From Figure 2 it is clearly shown that PI decreased up to 6% addition of both chemical compounds. At 6% addition of the chemical compounds the value of PI for NaCl was found 7.96% and $CaCl_2$ was 5.95%. Then the values were increased for the addition of 8 and 10% of chemical compounds. Therefore, the stabilized soil with NaCl showed comparatively higher value of PI than stabilized soil with $CaCl_2$.

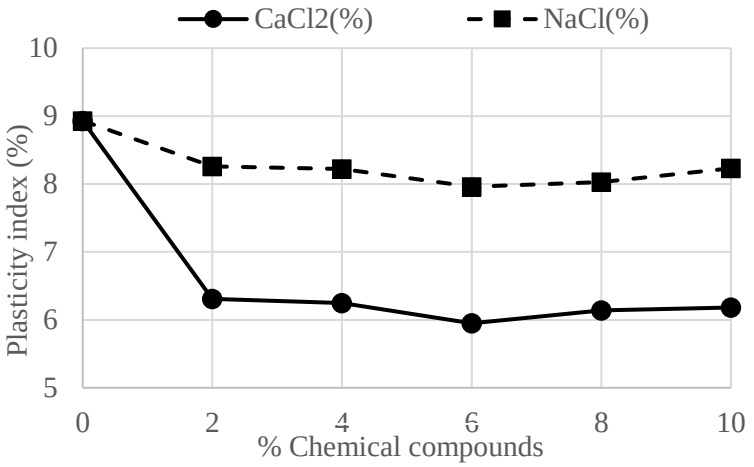

Figure 2: Comparison of PI of stabilized soils with chemical compounds.

3.2 Effect of chemicals on compaction properties

In this study, stabilized soils were prepared with NaCl and $CaCl_2$ as well as the compaction properties in terms of optimum moisture content and maximum dry density of stabilized soils were computed. The effect of NaCl and CaCl2 on the compaction properties is shown in Figure 3a and Figure 3b, respectively.

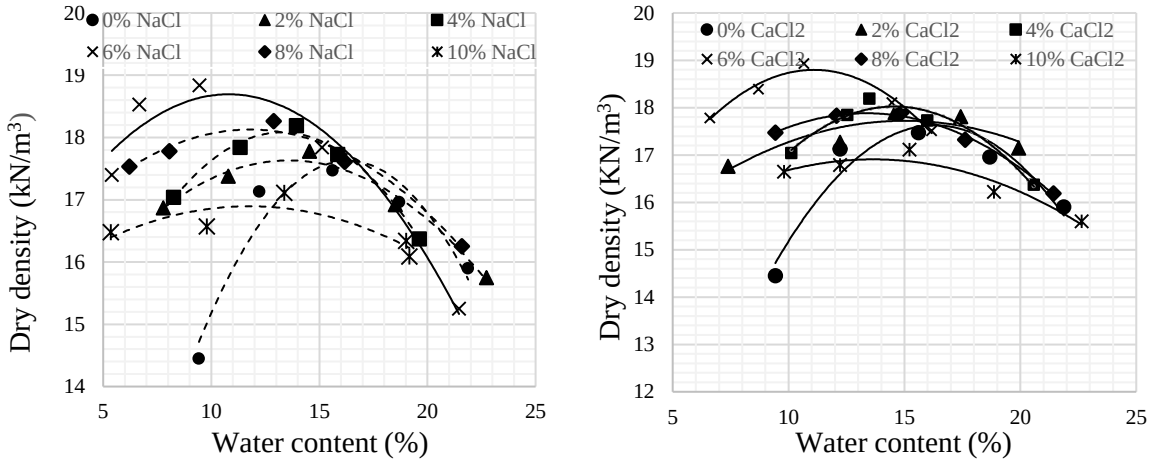

Figure 3: Effect of chemicals (a) NaCl and (b) $Cacl_2$ on compaction properties of stabilized soils

It was observed that there was a significant increase in maximum dry density with increase the percentages of the $CaCl_2$ up to 6%, beyond this percentage the maximum dry density rapidly decreased and vice-versa for optimum moisture content. Similar results were reported by Swarna et al. (Swetha, 2016) They attributed this behavior to the fact that at low moisture content the soil structure (before compaction) tends to change from edge-to-face type of flocculation to face-to-face flocculation (salt flocculation) with the increase in salt concentration (Lambe, 1958). Consequently under the influence of dynamic compaction, the clay particles become more oriented and the compacted dry unit weight increases with the increase in salt content. The decrease in the optimum moisture content as the salt content increased may be explained due to the higher the face-to-face flocculation the lower is the amount of water required for lubrication (T. ABOOD, 2007).

3.2.1 Comparison of compaction properties of stabilized soils with chemicals

The comparison between dry density and water content of stabilized soils with chemicals at 6% is shown in Figure 4. To compare the performance of these two chemicals at mixing proportion 6%, depicts stabilized soil with $CaCl_2$ showed the comparatively higher value of optimum moisture content than stabilized soil with NaCl and maximum density was found very close to each other. The strength may higher for 6% addition of NaCl into soil because of less optimum moisture content than 6% addition of $CaCl_2$

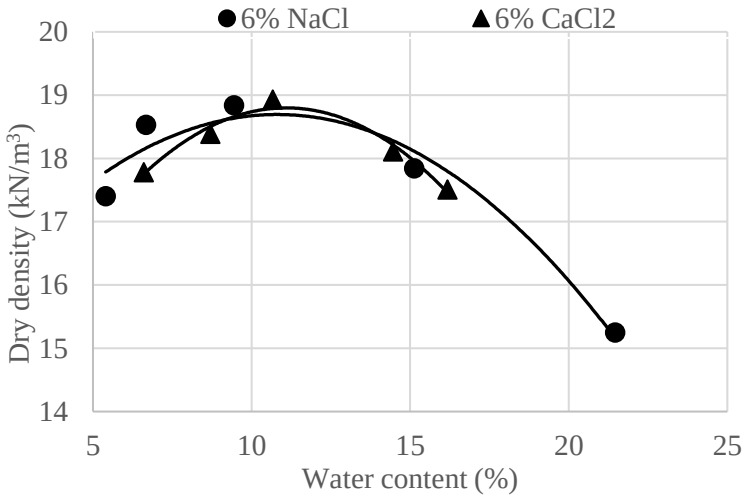

Figure 4: Comparison of dry density and water content of stabilized soils with chemical compounds at 6%.

3.3 Variation of unconfined compression strength of soil stabilized with chemicals

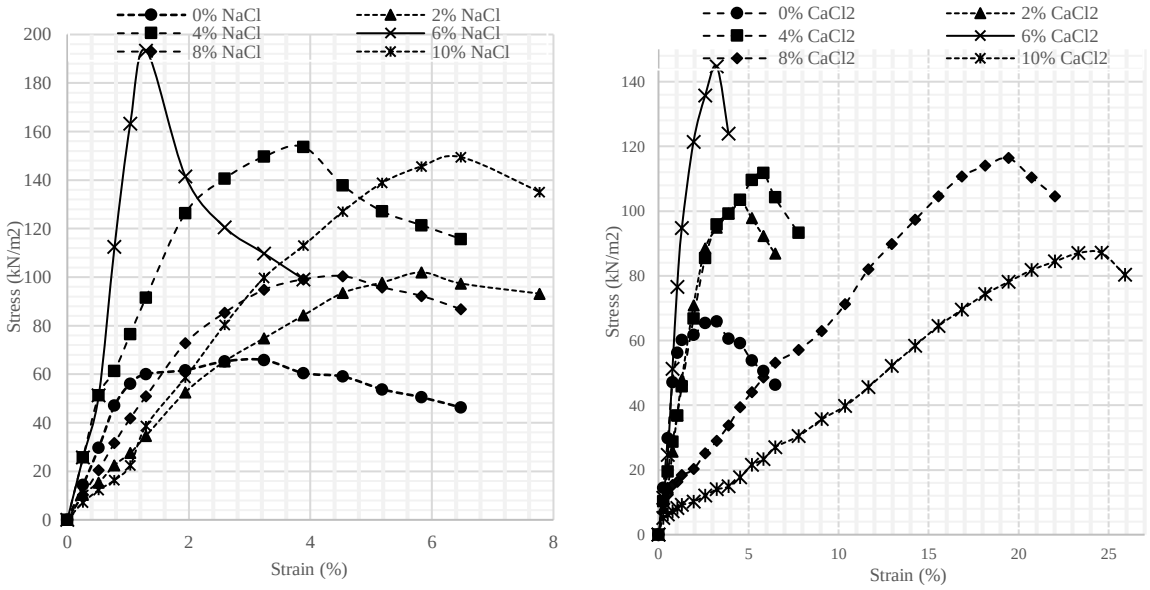

Figure 5: Effect of (a) NaCl and (b) $Cacl_2$ on unconfined compression strength of stabilized soils.

In this study, stabilized soils with NaCl and $CaCl_2$ were prepared and the unconfined compression strength (UCS) of stabilized soils were measured. The variation of UCS of stabilized soil with the addition of chemicals is shown in Figure 5a and 5b respectively. It was observed that UCS of stabilized soils increased with increase in percentage of both chemical compounds to the soil. Significant increase of UCS in stabilized soil with addition of chemical up to 6%, beyond this percentage the UCS decreased. The addition of salt to the soil causes an increase in the ion concentration of the pore water with concomitant reduction in the double layer thickness and this, in turn, causes a reduction in the antiparticles repulsion and an increase in the attraction, resulting in the increase in cohesion (Perloff W. H., 1976). The unconfined compressive strength is also effected by compaction effort. At 6% addition of the chemical compounds the value of UCS of stabilized soils for NaCl was 193.42 kPa and for $CaCl_2$ was 144.70 kPa. Then UCS decreased for the addition of 8 and 10% of chemical compounds. The value of UCS of stabilized soils for $CaCl_2$ was less than the stabilized soils with NaCl. Therefore, stabilized soil with the addition of %6 NaCl gives the maximum unconfined compression strength among all. So the addition of 6% NaCl to the soil cause hardening and more strength as compared to the soil specimens containing other salts additives.

4. CONCLUSIONS

This study was conducted to the know effect of adding chemical compounds (NaCl, $CaCl_2$) on the properties of fine-grained soils. Soil samples were tested for its liquid limit, plastic limit, dry unit weight, moisture content and unconfined compressive strength. The addition of both chemicals increased the plasticity properties for soils up to 6% and then decreased for 8 and 10% chemical additives. The MDD increased and the OMC decreased with the increase in NaCl and $CaCl_2$ up to 6%. The UCS of stabilized soil increased with the addition of NaCl and $CaCl_2$ up to 6%, beyond 6% UCS rapidly decreased. Soil stabilized with NaCl showed comparatively higher plasticity properties, UCS than soil stabilized with $CaCl_2$. This could help improving soil strength and other soil properties.

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